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THE EFFECTS OF POLLUTION CONTROL ON THE NONFERROUS METALS INDUSTRIES

ZINC

Part II

Structure of the Industry

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CHARLES RIVER ASSOCIATES INCORPORATED CAMBRIDGE, MASSACHUSETTS

December 1971

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CHARLES RIVER ASSOCIATES INCORPORATED

THE ECONOMIC EFFECTS OF POLLUTION CONTROLS ON THE NONFERROUS METALS INDUSTRY: ZINC

Prepared for
the Council on Environmental Quality

Prepared by
Charles River Associates Incorporated
16 Garden Street
Cambridge, Massachusetts 02138

December 1971

PREFACE

This report on the economic effects of pollution controls on the zinc industry has been organized into three parts comprised of eight chapters. The three parts can be read separately or in conjunction with one another. Part I summarizes the contents of the succeeding two parts, providing a broad profile of the zinc industry and outlining the economic effects of pollution controls on the industry. The important points and conclusions of the full report are contained in the first part, with greater detail and analysis in the following two parts.

Part II comprises separate chapters on:

Trends in supply and the technology of production
Consumption
Structure of the industry
Prices
Government policies
The zinc industry in the United States

Part III is our detailed analysis of the economic effects of imposing pollution controls on the zinc industry.

Much of the information contained here was first published in Charles River Associates Incorporated, *An Economic Analysis of the Lead-Zinc Industry* (Cambridge, Mass., 1967, rivised 1969), which we prepared under contract with the General Services Administration. Data presented in this report if not otherwise attributed is taken from our GSA report.

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PART II

Chapter 2

TRENDS IN SUPPLY AND TECHNOLOGY OF ZINC PRODUCTION

Zinc mining and smelting are distributed throughout the world. Nearly 50 countries report mine production, while about 25 are engaged in smelting. These activities experienced moderate growth over the decade from 1960 to 1970: noncommunist world zinc ore production grew at a 4.6 percent compound rate and slab (smelted) zinc output expanded at a slightly higher rate. The shares of different countries in this growth were relatively stable, with important exceptions. The United States saw sharp declines in its shares of ore and slab production. Canada nearly doubled its share of world ore production, and Japan more than doubled its share of slab zinc output. (See Table 2-1.) These trends are likely to continue, with mining expansion expected in Canada, Australia, Peru and Mexico, and slab zinc output growth in each of these countries and Spain, Holland and Japan. The

Table 2-1a

MINE OUTPUT OF ZINC BY MAJOR PRODUCTING COUNTRIES

	1960		1970	
	Short Tons	Percent of Total	Short Tons	Percent of Total
United States	435,427	15.9	546,772	12.5
Canada	430,049	15.7	1,211,298	27.9
Mexico	299,192	10.9	293,652	6.8
Australia	273,043	10.0	407,957	9.4
Peru	196,344	7.2	337,304	7.8
Japan	172,768	6.3	308,290	7.1
Noncommunist World	2,736,192	100.0	4,343,161	100.0

SOURCE: ABMS *Yearbooks*, 1966 and 1970.

Table 2-1b

OUTPUT OF SLAB ZINC BY MAJOR PRODUCING COUNTRIES

	1960		1970	
	Short Tons	Percent of Total	Short Tons	Percent of Total
United States	799,516	30.2	886,748*	20.4
Canada	260,968	9.9	460,665	10.6
Belgium	247,248	9.3	258,765	5.9
West Germany	199,729	7.6	332,431	7.7
Japan	175,640	7.5	745,430	17.2
France	159,686	6.2	246,555	5.7
Australia	130,436	5.1	287,255	6.6
Noncommunist World	2,646,396		4,338,808	

SOURCE: ABMS *Yearbooks*, 1966 and 1970.

*The 1970 output figure may not be indicative of the United States' position, as it represented a more severe decrease from 1969 output than was the case for other countries. In 1969 the U.S. produced 1,045,449 short tons of primary slab zinc, or 23.4 percent of 1969 total noncommunist world production. However, since 1969 6 smelters representing about 30 percent of 1969 U.S. capacity have been shut down.

noncommunist countries' share of total world output has remained stable at more than 75 percent in both ore and slab zinc output.

International trade patterns have shown little change over the past decade. Of the leading ore producing countries, four are major exporters: Canada, Mexico, Peru, and Australia. Each of these countries is rapidly expanding its domestic smelting capacity in order to process more of its ores within its own borders. The United States and Japan, as well as most European countries, are persistent importers of ore.[1] Of the leading slab zinc producing countries, three are also major exporters of the metal: Canada, Australia and Japan.

The principal forms in which zinc is imported into the United States are ores and slab zinc. Ores are imported principally for smelting by domestic primary producers. The share of domestic primary producers' output made from foreign ores has varied considerably since the late 1940's, but with a rising trend. Over the years from 1949 to 1953 this share averaged 34 percent, as compared with 54 percent over the years from 1966 to 1969. In 1970, U.S. primary producers obtained about one-half of their ores from foreign sources. Canada and Mexico together accounted for 42 percent of

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[1]There is some evidence that an important change in the direction of ore trade patterns is underway. Foreign smelters appear to be attracting some ore supplies, from sources both within and outside of the U.S. that formerly went to U.S. smelters. The explanation may be an increasing advantage on the part of relatively new, low-cost foreign smelters in bidding for these supplies.

total U.S. ore supplies. The share of imported slab zinc in U.S. consumption of slab has also increased, rising from an average of 16 percent over the 1949-1953 period to 21 percent in 1966-1969. In 1970 slab imports were 23 percent of U.S. slab consumption. The share of zinc metal imports in total U.S. supply, which includes ores and scrap not smelted, increased from 10 percent in 1962 to 16.5 percent in 1970. Canada, Peru, Japan, and Australia accounted for 80 percent of zinc metal imports in 1970 (See Figure 2-1).

Zinc Ore

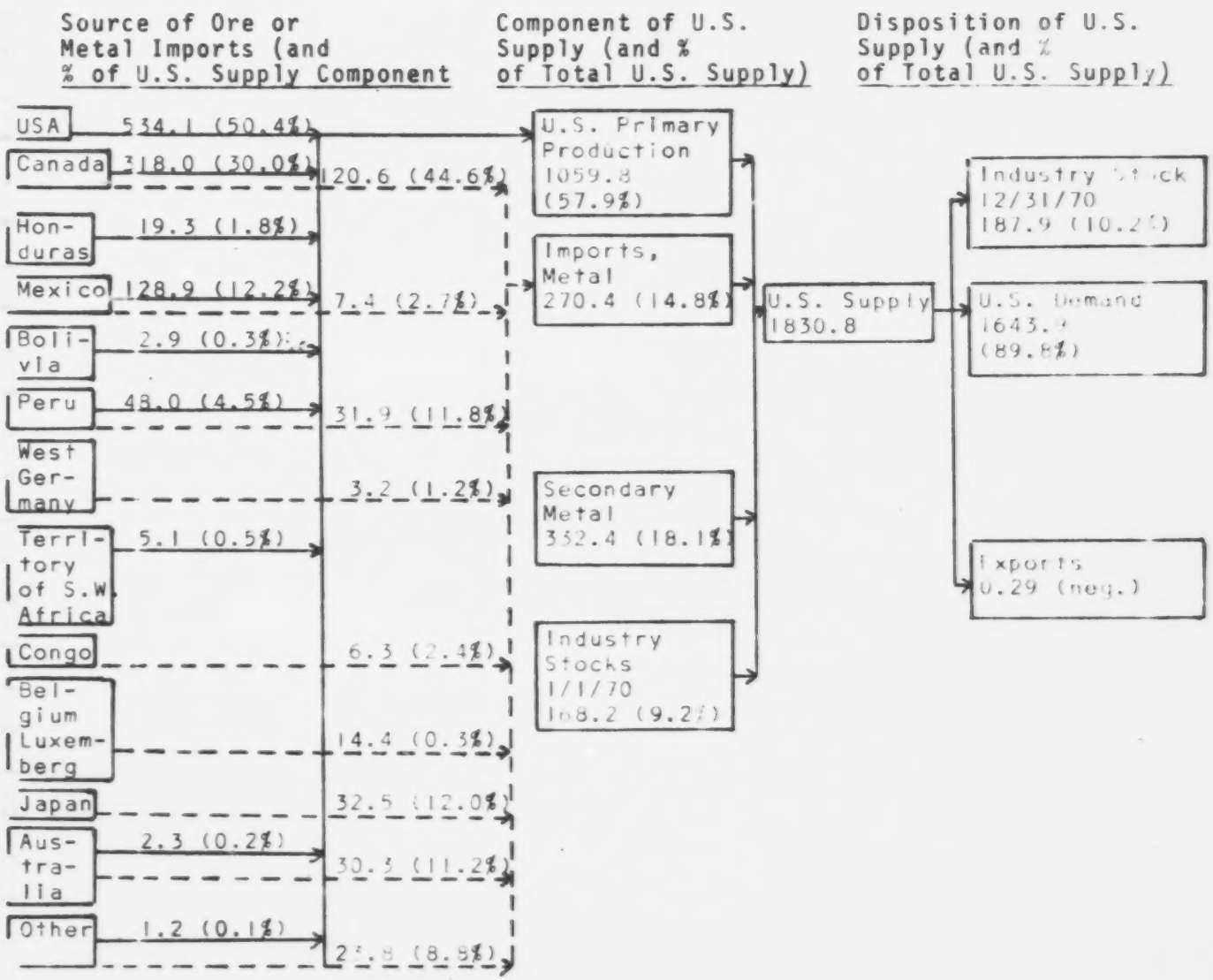
Zinc occurs in a variety of minerals that differ considerably with respect to their content of zinc and other recoverable metals such as lead, iron, copper, gold, and silver. The most common zinc minerals are sphalerite (zinc sulfide) and its oxidation products, smithsonite and hemimorphite. A separate group of zinc minerals, occurring in an important New Jersey deposit, are zincite, willemite, and franklinite.

Known ore reserves are dependent upon the state of the economy and relative prices: when demand presses against existing supply, exploration activity is stepped up and additional ore bodies are discovered and developed in step with increased extraction from existing mines. Thus world ore reserve estimates are subject to considerable change. In the 1965 edition of the U.S. Bureau of Mines' *Mineral Facts and Problems*, world reserves were estimated to be 85 million tons, of which 12.2 million (or 14.4 percent) were in the

Figure 2-1

IMPORTS AND U.S. SUPPLY OF ZINC 1970

(Thousands of Short Tons)



SOURCE: *Mineral Industry Surveys*, U.S. Bureau of Mines, January 1970 - December 1970. *Minerals Facts and Problems, 1970*, U.S. Bureau of Mines.

United States. In the 1970 edition, world reserves were estimated to be 124 million tons, of which 34 million tons (or 27 percent) were in the United States. Exploration and mining activity since that time has resulted in large additions to world reserves, especially from Canada. An important example is cited in the 1969 edition of the Bureau of Mines' *Minerals Yearbook*, which reports that the new Anvil Mine in the Yukon had reserves of 63.5 million tons of recoverable zinc as of April 1969.

There are generally four stages in the transformation of zinc ore into commercial metal: mining, milling, smelting and refining.

Mining

Most of the world's zinc ores are extracted from underground mines, but some of the new Canadian supply is taken from open pit mines. Mining consists in drilling, blasting, and removing broken rock. These processes have become increasingly mechanized over the past three decades, with resulting declines in labor requirements per unit of output.

Mining Costs

It is possible to characterize mining costs for what can be considered as a representative mine, although the level of costs varies considerably among mines. The typical mining company has large fixed costs, sharply increasing short-run costs, and fairly constant average costs both for moderate output changes in the intermediate term and for substantial output

changes in the long run. The intermediate term refers to a period of one to two years in which additional skilled workers and specialized heavy mining equipment can be acquired, and in which new excavations in existing mining areas can be prepared. For shorter periods than this, output increments can be achieved by working the higher grade ore sections of existing mines more intensively, which is costly.[1] Over periods longer than two years, more active exploration and development of new mines can add to mine output; in the past this has occurred without significant increases in unit costs. For decreases in output, the large fixed cost component -- roughly one-fifth of total intermediate term costs -- imposes sharply rising costs.[2]

Milling

Milling -- the process of separating the mined ore into concentrates of its various metal constituents -- is considered an integral part of the mining operation, and mills are located as near the mining site as feasible. The processes of crushing, floating, and concentrating have changed very little over the past three decades, but automation has increased both efficiency and recovery.

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[1] If idle men and equipment and unused but prepared excavations are available, short-run output increments can be obtained at constant cost.

[2] This proportion is based on information contained in *Census of the Mineral Industries* (1963).

Pollution Aspects of Zinc Mines

The processes involved in the mining and milling of zinc are similar to those associated with lead. According to the U.S. Bureau of Mines, most zinc mines are located in sparsely populated areas. Underground mines require a small surface area for buildings, equipment, and waste disposal. Some part of mine wastes are commercially utilized, and much of the rest is returned to the mine as backfill or is dewatered and impounded, thus checking stream and air pollution.[1] Dust emission from mining and milling operations is controlled relatively easily and presents much less serious problems than smelting.[2]

Smelting and Refining

The concentrates produced at the mills must be subjected to further treatement for recovery of zinc metal. There are several metallurgical recovery processes available, the choice among them depending upon a variety of technological and economic considerations such as concentrate characteristics, fuel or energy source, and desired output grade.

Concentrates are first roasted in preparation for the recovery process. In the roasting stage, heat and oxygen are applied to convert zinc sulfides into a higher state of oxidation -- such as zinc oxide or zinc

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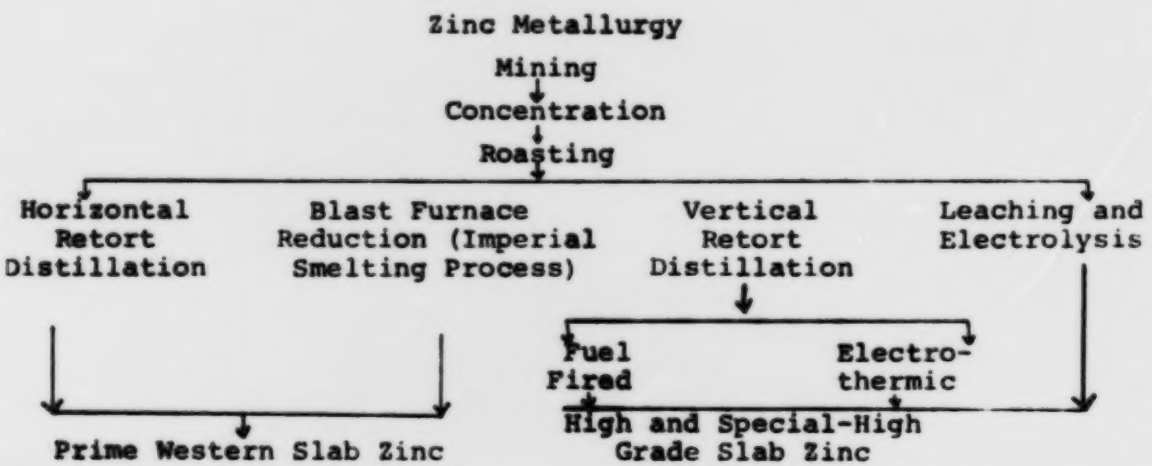
[1] *Mineral Facts and Problems* (1970), p. 818.

[2] Arthur Stern, ed., *Air Pollution* (New York: Academic Press, 1968), Vol. III.

sulfate -- and to remove sulfur in gaseous oxide form. The reduction and recovery of zinc is then achieved either by a pyrometallurgical process -- such as horizontal retort distillation, vertical retort distillation, or blast furnace reduction -- or by a hydrometallurgical process -- separation of soluble materials in sulfuric acid (leaching) and deposition of the dissolved zinc upon a cathode by electrolysis. The horizontal retort and blast furnace (Imperial Smelting Process) methods produce the lowest purity grade of slab zinc. This grade can then be refined to higher purity grades. The vertical retort and electrolytic processes produce the higher grades of slab zinc. These grades can then be converted to lower grades by remelting, adding contaminants, and recasting. Thus any smelter technology can be used, with supplementary processes, to produce the full range of slab zinc purity. However, it is often cheaper to refine towards higher grades than to convert to lower grades.

The following schematic classification, adapted from the Bureau of Mines' *Minerals Survey: Zinc*, is useful.



The distillation retort furnaces employ coal or coke as the reducing agent. Zinc is vaporized in the retort, collected as liquid metal in an attached condenser, then cast into slab form. The zinc metal grade may be increased by a refining process -- usually redistillation -- to eliminate impurities. At electrolytic plants, roasted concentrate is leached with sulfuric acid, then put into electrolytic cells, where the zinc is deposited on aluminum cathodes. The cathodes are removed from the cells and stripped of zinc, which is then melted in a furnace and cast into slab form. In the Imperial Smelting Process, zinc is reduced and vaporized in a blast furnace, and then condensed.

The Imperial Smelting Process may be more suitable for those ores in which the constituent materials appear in a sort of "solid solution," and less suitable for ores in which lead and zinc are distinct. For the appropriate ores, this process achieves high recovery rates both for lead and zinc and for other constituents such as copper, gold, and silver.

The horizontal retort method is the oldest and generally most costly of these processes, and all but the Imperial Smelting Process were developed before World War II. The IPS, which as introduced commercially around 1960, has grown rapidly throughout the world. This expansion may be tapering off, due to the relative unsuitability of the technology when applied to a variety of ore types. There is disagreement regarding the future of ISP. Industry sources in the United States expect little additional world ISP capacity. Industry sources in the United Kingdom have predicted that the ISP will supply about 25 percent of

world slab zinc production by the middle of the 1970 decade.[1] So far it has not been adopted in the United States due to the nature of domestic ores.

UNITED STATES PRIMARY ZINC
CAPACITY BY SMELTER TYPE
(Thousands of Short Tons and Percent of Total)

	1949	1969	1971
Horizontal Retort	406 (41.3%)	317 (24.4%)	204 (22.6%)
Electrolytic	363 (36.9)	551 (42.4)	377 (41.8)
Vertical Retort			
Fuel Fired	141 (14.3)	220 (16.9)	110 (12.2)
Electrolytic	74 (7.5)	210 (16.2)	210 (23.3)
Total Production	984	1,298	901
Number of Smelters	18	14	8

SOURCE: Bureau of Mines, *Materials Survey: Zinc*, p. VI-20 *Metals Week*, October 11, 1971, p. 21.

In the United States, the share of capacity provided by horizontal retort smelters has markedly decreased, while those of electrothermic and electrolytic zinc plants have increased. The number of smelters has decreased and their scale of operations increased.[2] For the world as a whole the displacement

[1] *Technological Developments in Lead and Zinc Production and Their Significance to Developing Countries*, United Nations, 1970, p. 47.

[2] Anaconda Company recently announced its intention of closing its electrolytic zinc smelter in 1972. This would reduce U.S. primary zinc capacity to 739,000 tons per year, allocated among seven smelters. The share of electrolytic capacity would drop to 29 percent of the U.S. total. The shares of other smelter types would be correspondingly increased: horizontal retort capacity would account for 28 percent, fuel fired vertical retort for 15 percent and electrothermic for 28 percent. It is quite possible, however, that horizontal retort capacity will be greatly reduced by that time.

of horizontal retort technology is due to the expansion both of electrolytic plants and the Imperial Smelting Process.

WORLD PRIMARY ZINC CAPACITY BY SMELTER TYPE
(Percent of Total)

	1959	1968
Electrolytic	51.0%	59.2%
Horizontal Retort	33.4	16.0
Vertical Retort		
Fuel Fired	10.9	8.6
Electrothermic	4.1	5.7
Imperial Smelting Process	0.6	10.5

The increasing cost advantage of the other processes relative to the horizontal retort process is attributable to the greater efficiency of nearly all inputs. The type of retort fire clay used by horizontal retort plants is an important determinant of plant location. Other processes use refractories which are not dependent on local clay supplies. A similar difference exits in the case of fuel. The preferred fuel for horizontal retorts is natural gas, while other methods are more flexible, being able to use producer gas, coal, or electricity. The other processes are able to produce the higher-purity metal being demanded by consumers from the same or lower grade ores, while the horizontal retort process is unsuited to the treatment of concentrates from complex ores unless they contain at least 60 percent zinc and have little iron, copper, or precious metal content. The horizontal

retort process has relatively high labor costs and low thermal efficiency. The only surviving horizontal retort plants in the United States are in the Oklahoma-Texas region of the natural gas belt, where suitable retort clays are available. Output from the Kansas, Oklahoma, and Missouri mines that have supplied these plants with suitably clean concentrates has been progressively declining, and in view of this there is little incentive to invest in plant modernization.

The horizontal retort process is likely to die out altogether. Expansion of vertical and electrothermic capacity will probably be associated with existing rather than with new plants. The electrolytic process is likely to expand, especially where electric power is cheap relative to coke. This process has also been made more attractive by recent technological advances which have substantially improved recovery rates. Relatively cheap coke and suitable ores may favor the Imperial Smelting Process. The latter may also be better suited to larger-scale production.[1]

Pollution Aspects of Zinc Smelting and Refining

The major waste emission problems associated with zinc production arise in the roasting stage of the production process, where sulfur dioxide gas is emitted. This problem is more severe if the subsequent zinc

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[1] *Technological Developments in Lead and Zinc Production and Their Significance to Developing Countries*, United Nations, 1970, Chapter 3.

recovery is by means of retort distillation than if by electrolysis, because more complete removal of sulfur from the concentrate is required by the distillation method.[1] The distillation process itself gives off very small amounts of sulfur dioxide, and the electrolytic process gives off practically none. Some retort distillation plants give off a zinc oxide fume which would be difficult to control under a set of stringent particulate emission standards, as the value of the recovered material would be small relative to recovery costs.

The only method currently in use for removing sulfur dioxide from retort discharge gases is the contact process of producing sulfuric acid.[2] According to the Bureau of Mines, economic operation of acid plants requires the gas to contain at least 3.5 to 4 percent sulfur dioxide and that the older roasting equipment normally discharges a more dilute gas.[3]

Smelting and Refining Costs

As in the case of mining, it is possible to describe smelting costs for what can be considered the representative smelter. Plants using retort distillation

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[1]Sulfur recovery costs are also greater for older, small-capacity roasting equipment. The gases discharged from these roasters are more dilute in sulfur dioxide content that are the discharge gases of newer equipment.

[2]Other emission control methods include the use of taller chimneys or stacks and variation of smelter operation according to atmospheric conditions.

[3]Bureau of Mines Information Circular 8527, *Control of Sulfur Dioxide Emissions in Copper, Lead and Zinc Smelters*, 1971. This publication also contains a useful discussion of the status of technology for removing sulfur dioxide from smelter gases and various approaches to the problem.

methods will have cost levels different from those of electrolytic plants, and there is probably some variation within these categories. The short-run cost schedule of each type of zinc smelter is probably U-shaped. Short-run changes in smelter output involve smaller cost changes than in mining. For output increases it is easier in smelting to add labor and equipment, while for output decreases the lower proportion of fixed costs in the total cost of smelting as compared with mining implies less sharply rising unit costs. As the electrolytic process is more capital intensive than the retort distillation process, its fixed costs are a larger proportion of total costs. This proportion may be about 30 percent for electrolytic plants and about 10 percent for distillation plants. Thus short-run decreases in output at electrolytic plants may involve greater unit cost increases than at distillation plants. The cost of concentrates is approximately one-half of the total slab zinc cost at electrolytic plants.[1]

For the long run, smelter costs per unit are probably nearly constant for large scale output. It appears that economies of scale are attained with plant sizes in excess of 50,000 tons of slab zinc per year.

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[1]U.S. Department of the Interior, Bonneville Power Administration, *Copper, Lead and Zinc Industries in the Pacific Northwest*, 1966, p. 25.

Chapter 3
CONSUMPTION OF ZINC

Zinc is used predominantly as an input in the production of other commodities, and very little as a final commodity. Zinc's durability, hardness, light weight, and low melting point make it very effective in the die casting of mass produced objects involving simple or complex shapes with great dimensional accuracy. These die cast products are used extensively as functional and decorative components in automobiles, appliances, and office equipment. Extreme corrosion resistance makes zinc particularly valuable as a galvanized protective coating of other materials and in a variety of outdoor uses in the form of wire, sheet ribbon, and other shapes. Zinc accepts finishes well and combines readily with other elements to make a number of alloys, notably brass. These three categories accounted for 75 percent of domestic consumption in 1970. The remaining uses are as inputs into a wide range of products that includes paints, ceramics, medicines, rubber tires, battery cans, organ pipes, and toys.

Domestic Consumption

As indicated by the following data, zinc consumption in the United States has not grown very rapidly over the past two decades.

Domestic Zinc Consumption Classified by End Use
(Thousands of Short Tons and as a Percentage of U.S. Total)

End Use	1950	1958	1962	1969
Galvanizing	338.1 (29.5)	321.1 (30.9)	307.3 (26.7)	375.9 (24.1)
Die Casting	288.6 (25.2)	310.5 (29.9)	418.4 (36.7)	573.1 (36.7)
Copper Base Alloys	163.9 (14.3)	167.8 (16.2)	114.9 (10.1)	213.5 (13.7)
Other	346.1 (30.2)	281.1 (27.1)	257.9 (22.6)	399.5 (25.6)
TOTAL	1146.6	1038.1	1140.3	1562.0

SOURCE: 1969 CRA Lead-Zinc Report and ABMS *Yearbook*, 1970. The CRA report, pp. 29-30, describes the derivation of these figures, which include both slab zinc and other forms of elemental zinc.

Total consumption has grown at about a 1.7 percent average annual compound growth rate from 1950 to 1969. Consumption of copper base alloys -- primarily brass -- has grown about the same rate, the galvanizing and "other" categories have grown more slowly, while use of zinc die castings has grown at a rate of about 3.6 percent. Die castings have emerged as the leading use, accounting for 37 percent of total domestic consumption. Galvanizing is the second major use category, contributing 24 percent of the total.

Copper base alloys are the third largest single category, with 14 percent.

Foreign Consumption

As in the case of lead, Europe's consumption of zinc was in more traditional uses until quite recently, when it began extensive use of the metal in the automotive and appliance technologies developed earlier in the United States. Japan's rapid postwar growth has also created large markets for the more modern uses of zinc. Thus the total consumption of zinc in these major industrial areas has grown more rapidly than in the United States. European consumption of slab zinc grew at about a 4.3 percent average annual compound growth rate from 1957 to 1969, that of Japan grew at nearly 14 percent, while for the total noncommunist world, slab zinc consumption growth averaged a 6.2 percent growth rate.

WORLD CONSUMPTION OF SLAB ZINC
(Thousands of Short Tons)

Year	Europe	Japan	Other	Total Noncommunist World
1957	1030.4	142.6	286.7	1459.7
1960	1242.7	208.7	368.2	1819.6
1965	1415.7	363.2	513.8	2292.7
1969	1715.3	658.1	655.6	3029.0

SOURCE: *Metalgesellschaft*, various issues.

The largest foreign consuming countries in 1969 were Japan (22 percent of total foreign noncommunist consumption, West Germany (14 percent), the United Kingdom (11

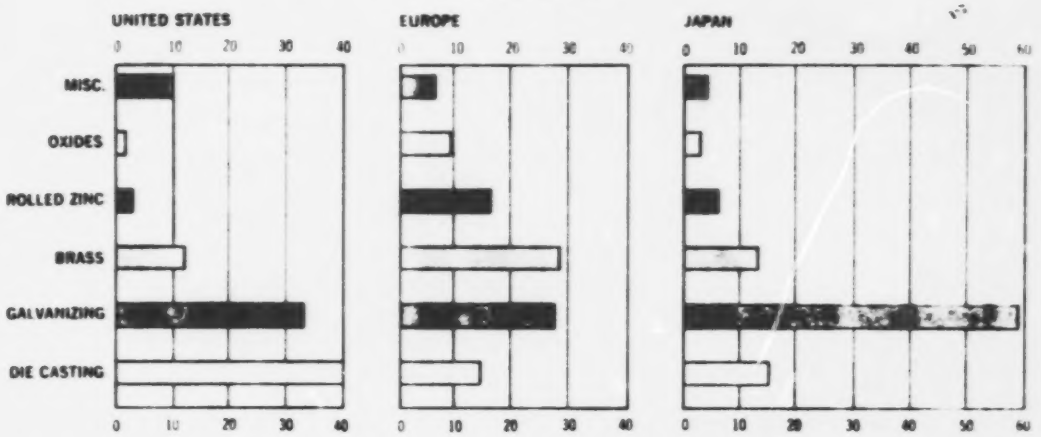
percent), France (9 percent), and Italy (6 percent).

It is not possible to represent noncommunist world zinc consumption on the same basis as for U.S. consumption. The data that are available, illustrated by the figure below, do indicate substantial differences between the consumption patterns of the major industrial areas. In Europe there is greater emphasis on rolled zinc and brass, and compared with the United States much less emphasis on die casting. Greater similarity is observed between the Japanese and U.S. consumption patterns. Although there is relatively greater emphasis in Japan on galvanizing uses and less on die casting, that difference appears to have diminished since 1966.

ZINC

END USE CONSUMPTION PATTERNS 1966

Per Cent of Total



SOURCE: Lead and Zinc, Free World Supply and Demand Lead Industries Association and Zinc Institute, Inc. p. 11.

U.S. End Use Categories

The end use categories that are listed in the U.S. consumption table are useful for an analysis of trends in various components of zinc consumption.[1] As these trends are influenced by technological developments relating to substitute products, a closer examination of these categories is appropriate.

Zinc Die Casting

A product is die cast by forcing liquid metal into a mold or die, the cavity of which corresponds to the shape of the product desired. The die opens and shuts rapidly and repeatedly, receiving molten metal upon closing and ejecting a complete product upon opening. The physical properties of zinc and the nature of die casting make this a very suitable method for mass producing dimensionally accurate products with complex shapes.

Available date do not permit a detailed description of end use distributions within the die casting category. An approximation to this distribution is given by data on sales of custom zinc die castings, although this probably understates the relative importance of motor vehicle

[1]The end use category labelled "other" includes such a large number of applications, each of which constitutes very small share of total zinc consumption, that further disaggregation does not add substantially to the explanation of total consumption trends.

and home appliance use.[1] The total share of zinc die castings used by the automotive industry is probably between 50 and 60 percent, rather than the 48 percent indicated by custom shop data.[2]

ESTIMATED END-USE DISTRIBUTION OF SELECTED CUSTOM ZINC DIE CASTING SALES
(Thousands of Tons and as Percent of Total)

End Use	1964	1966	1968
Automotive	125.5 (48.0)	167.3 (44.9)	142.5 (44.7)
Home Appliances	40.0 (15.3)	59.5 (16.0)	51.0 (16.0)
Machinery and Tools	35.0 (13.4)	47.0 (12.6)	43.0 (13.5)
Plumbing, etc.	19.3 (7.4)	18.0 (4.8)	16.0 (5.0)
Electronic Devices	9.5 (3.6)	15.5 (4.2)	13.5 (4.2)
TOTAL	261.5 (100.0)	372.5 (100.0)	319.0 (100.0)

SOURCE: American Die Casting Institute, as presented in Bureau of Mines Information Circular 8505 *Materials Substitution Study: General Methodology and Review of U.S. Zinc Die Casting Markets*, p. 11.

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[1]Zinc die casting producers can be categorized either as custom shops or as captive shops, although this distinction is not absolute. The custom shop tends to be smaller, and sells its output to a variety of final goods manufacturers. The larger captive shops are owned or controlled by major users of zinc die casts, and automotive and appliance industries are increasingly important in the captive shop sector. The American Die Casting Institute has made data available for the custom

(footnote continued on following page)

The data in the custom die casting end use table indicate that automotive, home appliance, and machinery and tool applications account for nearly 75 percent of total zinc die casting use. The true proportion is probably substantially higher than this, as automotive and appliance applications account for larger shares of captive die casting. Thus the bulk of the die casting market is end uses in which the cost of zinc is a small proportion of the total costs of the final products in which it is embodied. This being the case, the demand for the commodities containing zinc die cast components is likely to be insensitive to changes in the price of zinc.

The demand for zinc by the automotive, home appliance, and machinery and tool industries, however, is almost certainly sensitive to changes in the price of zinc, as there are several important competing materials which may substitute for zinc in many die casting applications.

Throughout the range of zinc die castings use, the chief competitive materials are aluminum and injection

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shop sector, but none is available for the captive shop sector. According to the table in the text, 319,000 tons of zinc were sold by custom die casters in 1968. This is about 57 percent of the 563,000 tons of zinc consumed in die castings as reported in the 1970 ABMS *Yearbook*.

[2]E. F. Iverson, *Zinc in the Automotive Industry*, cited in the Bureau of Mines' *Materials Substitution Study*, p. 10.

molded plastics.[1] Zinc die castings, which were introduced commercially in the 1920's, have been subjected to competition from aluminum since the 1940's and from injection-molded plastics since about 1960. The shares of these materials in the die casting market have expanded markedly. An inverse relation between the quantity of zinc die castings consumed and both the ratio of the price of zinc to the price of aluminum, on the one hand, and the ratio of the price of zinc to the price of ABS plastic, on the other hand, has been evident over this time period. However, in econometric analyses performed by CRA the influence of price on demand has not been statistically significant. Levels of activity in the end use markets have been more important determinants of zinc die casting consumption trends.

RELATIVE PRICES OF ZINC AND SUBSTITUTE MATERIALS IN DIE CASTING

	Price of Zinc Divided by Price of Aluminum	Price of Zinc Divided by Price of ABS Resins
1947-52	1.20	N.A.
1953-59	0.79	0.22
1960-64	1.02	0.27
1965-69	1.18	0.34

SOURCES: The prices of prime western grade slab zinc and ABS resins are from the Bureau of Mines, Information Circular 8505, *Materials Substitution Study: General Methodology and Review of U.S. Zinc Die-Casting Markets*, 1971. The price of U.S. aluminum scrap was used as it is more indicative of trends in aluminum transactions prices than is the list price of primary aluminum ingot. The scrap price is from the CRA study, *An Economic Analysis of the Aluminum Industry*, 1971.

[1] The most important competitive plastic, from the standpoint of zinc die casting, is acrylonitrile-butadience-styrene (ABS).

There are several reasons for the inability of econometric investigation to reveal a statistically significant relation between quantity and price in the zinc die casting market. As earlier CRA studies pointed out, the typical reaction to an increase in materials cost is an intensified research effort. The time lag between such effort and commercial introduction of an alternative material or method can be substantial, as the technological breakthrough must be made, followed by market testing, design, installation and operation of new equipment, and sales effort. Furthermore, this kind of time lag varies among instances of changes in relative materials prices. Thus the channel through which price changes exert their influence is indirect, irregular, and not readily identifiable by the kind and amounts of data available.

A second reason for the apparent insensitivity of die casting demand to zinc prices is that the materials prices are neither the same as the die cast product prices nor the same as the total systems cost. A complete listing of the production costs associated with the use of a particular material would include such costs as tooling and processing equipment, labor, scrap recovery and disposal, and finishing or plating.[1] The

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[1] In the automotive market, zinc must generally be finished (buffed) after it is cast. Despite recent improvements in finishing processes which have potential for substantial cost reductions, industry officials at the 1971 Zinc Institute meeting emphasized finishing costs as an important source of cost disadvantage in comparison with plastics. This disadvantage does not extend to the appliance market, where a larger proportion

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materials price is evidently not the overriding consideration in every instance, but in any case data are not available in suitable form on all these costs.

A third reason for the difficulty of measuring the sensitivity of substitution with respect to changes in relative materials prices is that zinc does not have any important substitutes in a substantial portion of die casting applications at current price levels, owing to the different physical properties of the various materials. As the 1969 CRA report pointed out, much of the growth of aluminum die casting is in uses requiring higher temperatures than zinc can tolerate. Moreover, entry of both aluminum and zinc into new end use areas appears to broaden the total market for die castings by means of expanding the acquaintance of metal working industries with the overall potential of die casting in a range of applications. Thus there is a complementary element in the relation between materials which to some extent offsets the substitution element, and it is not clear which element dominates in the long run.[1]

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of die cast components are structural. A second disadvantage discussed at the meeting is that die casting shops are not designed to handle the scrap collection and reuse problems associated with different alloys. Thus even though new alloys which would give zinc the advantage of particular applications are made available, die casting shops continue to use a single traditional alloy. A report of this discussion appears in the April 26, 1971 issue of *Metals Week*.

[1] *American Metals Market*, September 29, 1971, reports the introduction of a new die casting alloy into U.S. markets. The alloy, called Beric, has been used widely in Japan for several years and has significant potential in the automotive and appliance markets. It is made of

(footnote continued on following page)

Some substitutions have occurred in response to events other than price changes. According to industry sources, the issue of automobile safety has had a limiting effect on the use of zinc in instrument panels and other interior components, and in front end use where weight control was found to be important for braking effectiveness. On the other hand, the safety issue has stimulated compensating use of zinc in items such as seatbelt hardware and side marker lights. Then there are instances of decreased use of zinc due to styling changes, such as trends away from controlled ventilation windows and fender extensions in the 1967-1969 period, where no other material has been substituted. An important substitution phenomenon which is indirectly related to relative prices is the development of thinner zinc die casting walls, which permits zinc to retain its place in particular applications or to capture new uses because of the weight reduction achieved, but which reduces the amount of zinc used in these applications.

This discussion of the difficulty of measuring the timing and the strength of the effect of relative price changes on materials substitution is not to be interpreted as evidence that such an effect is in any sense weak. Both the trade literature and industry sources convey a sense of intensive competitive pressure,

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zinc, aluminum, copper, titanium, and berylium. It will probably substitute for both other zinc alloys and for plastics in a relation that is complementary with aluminum.

especially from plastics. Aside from the issues of automobile safety and styling changes, the important events in the zinc-plastic substitution history appear to be the commercial introduction of ABS in 1958 and of electroplated ABS in 1964. Both events were followed by marked reductions in the relative price of ABS and by increased use of injection molded plastics in automobiles. The ratio of the average annual price of ABS resins to the average annual price of prime western grade slab zinc, each in cents per pound, had an average value of 4.55 over the years from 1953 to 1959, with little variation. In 1960 the ratio of ABS to zinc prices dropped to 3.84, which was the average value -- with little variation -- until 1964, when it dropped again to 2.94. It remained virtually unchanged from 1964 to 1969.[1] The first decline in the average value of the ratio represented a 16 percent drop and the second a 23 percent drop in the price of ABS relative to that of zinc. It is quite likely that changes of this magnitude have stimulated the substitution of plastic for zinc in the past and would do so again in the future.[2]

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[1]These calculations are based on data contained in the Bureau of Mines' Information Circular 8505, *Materials Substitution Study*.

[2]The March 29, 1971 issue of *Metals Week* reported on recent tests demonstrating a cost-performance superiority for zinc die casts over plastics with present prices and technology. The tests compared zinc with five injection molding grade thermoplastics with respect to various engineering properties, using plastic industry standard testing procedures. The April 26, 1971 issue of *Metals Week* reported that the plastics industry is much more successful in getting information to the appliance

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Die Casting Trends

It appears that no large changes will occur over the next few years in the shares of these materials in the die casting market, or in the moderate growth rate of the total die casting market. The growth of automobile production and home appliances is likely to be more important for zinc die castings than either changes in relative prices foreseeable in market trends alone or than implementation of technological advances. The loss of die cast market experienced by the zinc industry in the 1960's seems to have prompted it to greater effort with respect to process automation, more efficient finishing methods, thinner wall casting, and new alloys. This effort is likely to enable zinc to hold its own against the newer materials emerging from the plastics industry.

The 3.7 percent growth rate observed for zinc die casting over the 1950 to 1969 period is probably below the rate that can be expected in the future, as it has been influenced by abnormal events. Die casting grew much more rapidly to a maximum of 638,000 tons in 1965, from which it declined to 535,000 tons in 1967. This decline was due to the combined effects of a decrease in the number of automobiles produced and to an increase in the use of injection-molded plastics substitutes. Zinc die casting then increased in 1968 and 1969, but

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manufacturer design engineers. These two reports suggest that relative marketing and information efforts by the different industries may be important influences in the history of materials substitution.

dropped off in 1970 due to abnormally low automobile production and to the general economic slowdown.

If zinc die castings do hold their own against further competitive intrusion, then the die casting growth rate will probably move up to about 5 percent per year over the long run.

Galvanizing

Zinc coatings applied by hot-dip galvanizing and electroplating are a major form of corrosion protection for steel products. Over one-half of the consumption of zinc for galvanizing, both in the United States and in the world, is in the form of sheet and strip, chiefly used for roofing, siding, and other building applications. Although construction is the most important user of galvanized products, the fastest growing market in recent years has been the automotive industry. Currently, about 5 percent of automobile steel is galvanized.[1] Tube, wire, and hundreds of miscellaneous steel products account for the remainder. Other zinc coatings, also used for rust protection, are largely noncompetitive with galvanizing and are quantitatively minor, accounting for less than 10 percent of all zinc used in coatings.

Potential substitution for galvanizing may be viewed at two levels: substitution between galvanizing and other means of protecting steel, and between corrosion protected steel and other materials. According to the International Lead Zinc Study Group, the cost of

[1] *Metals Week*, April 26, 1971.

zinc in coated articles generally ranges from 5 to 20 percent of total material cost, depending on the thickness of the coating and the product being protected.[1] Therefore, competition of galvanized steel with materials other than steel is likely to be much more heavily influenced by the price of steel than by the price of zinc.

However, the cost of zinc is often a major element in the cost of rust protection. As the price of zinc rises, it may well be that less rust protection is purchased. A thinner zinc coating may be a possibility. Also, rust protection is optional on many items. At higher prices, less of these items will be galvanized.

There are also alternative methods of steel protection other than galvanizing. These alternatives include aluminum coatings, painting, and rust resistant steel. Aluminum coatings are already available in a few fields, but technical difficulties must be overcome before widespread applications are feasible. Paints and other cheaper coatings have low materials cost, but application is generally labor intensive and consequently susceptible to increasing wage rates over time. The use of rust-resisting steels and galvanized coatings with reduced zinc content may be somewhat responsive to zinc prices.

Alternative materials to steel are numerous and vary with the use. Aluminum is the most pervasive

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[1] International Lead-Zinc Study Group, *Lead and Zinc: Factors Affecting Consumption*, United Nations, New York, 1966, p. 34.

substitute but the range of substitutes in construction uses alone includes copper, plastic, asbestos, asphalt singling, and lumber products.

Previous CRA studies have found the trends in zinc galvanizing consumption through the mid-1960's to be relatively well explained by trends in construction activity and the lagged real price of steel. Since the mid-1960's, however, the real price of steel has stabilized somewhat in response to import and substitute competition that can be expected to continue. Thus the statistical significance of the real price of steel has about disappeared for recent years. Many of the difficulties of measuring the effects of price changes which were discussed in connection with die casting appear to some extent in the galvanizing market. These effects are indirect, irregular, and of a longer-run nature than available data reveal.

The future markets for galvanized steel in bridges and other such exposed structures are likely to continue to grow as painting processes are more costly in terms of labor. The architectural market is also viewed as attractive for the use of galvanized steel in housing frames, siding, and many applications now using wood.

There appear to be two threats to the galvanized markets which are of concern to zinc producers. One is the recent development of electrophoretically applied paints which will probably reduce the amount of galvanized steel on automobiles. According to one industry official the impact of these paints had not been fully assessed and that as of yet there is no movement away from galvanized, but that "the future for galvanized as

an auto undercovering is not promising."[1] The second threat is from steel imports as galvanizing tends to occur in the country where the steel is produced. Foreign galvanized steel is about 19 percent of the U.S. galvanized steel market and is growing.

The net effect of these influences is likely to be a continuation of moderate growth of zinc consumption in galvanizing of perhaps 2 to 3 percent a year in the near future. Galvanizing accounted for about 24 percent of total U.S. zinc consumption in 1969.

Copper Base Alloys

Zinc can be alloyed readily with copper to form a wide range of brasses which are superior to copper alone in many uses with respect to strength, ductility, corrosion resistance and appearance. Some copper fabricators other than brass mills also use zinc, but their share in the total copper base alloy consumption is relatively small.

Zinc used in copper based alloys accounted for about 14 percent of U.S. consumption of zinc in 1969. The general categories of brass mill products are sheet, rod and wire, plumbing tube, and commercial tube. The end use areas for these products can be categorized as construction, transportation, consumer products, industrial machinery, and electrical or electronic products. Trends in durable production, which includes all these user categories except for construction and consumer

[1] *Metals Week*, April 26, 1971.

products that are closely correlated with them, are the major influence on trends in brass mill production and in zinc used in brass.

Earlier CRA studies found that the use of zinc in brass is quite insensitive to changes in the price of zinc. Zinc comprises up to 40 percent of the weight of brass alloys, the remainder being primarily copper. As copper prices typically exceed zinc prices by a factor of two to three, the proportion of zinc in terms of value is generally between 5 and 10 percent. Thus price-sensitive substitution between brass and other metals, most notably aluminum but to some extent also from steel, iron and plastics, is much more dependent on copper prices than upon zinc prices. Technical requirements give little scope for varying the zinc contents of specific brasses, so that zinc price changes can induce only very limited changes in the average proportion of zinc used in brass. High but volatile copper prices and periodic shortages during the past three decades appear to have been instrumental in encouraging the development of substitutes for brass in the U.S.

Consumption of zinc in brass grew fairly steadily at an annual rate of about 3.5 percent over the period from 1957 to 1968. A sharp increase in military uses occurred in the last years of the decade, but this use has decreased again over the past year and a half. A sustained growth rate in the neighborhood of 3 percent appears to be likely for this use of zinc over the next few years.

Other Zinc Consumption

The remaining uses of zinc -- oxides, sheet and strip, chemical, and miscellaneous applications -- have little in common except that the zinc contained in them is generally a small part of the cost of the final product. We would thus expect little if any substitution of other materials for zinc in these applications as a result of higher zinc prices.

Future Trends for Total Zinc Consumption

The long-term growth rate in the future is expected to be higher than for the past. This is due mainly to the strength of die casting markets, but also to expanded use of galvanizing and other uses. If the die casting market attains the 5 percent per year growth rate, as discussed earlier in this chapter, then the long-term growth rate of zinc consumption is likely to be nearly 4 percent per year. A lower forecast, based in the unlikely event of substitution of injection-molded plastics to such an extent that there was no further growth in zinc die casting use, would be about 2 percent.

Chapter 4

STRUCTURE OF THE ZINC INDUSTRY

Zinc is marketed both as a concentrate and as smelted slab or oxide. Because a substantial portion of the world's concentrate production is carried on by integrated firms and does not reach the market, our discussion of price and output focuses on the market for slab zinc.

For some purposes it is important to distinguish between primary and secondary zinc products. Of the 1970 total domestric supply of zinc metal, primary producers accounted for about 50 percent and secondary producers contributed about 18 percent. Suppliers of secondary products differ from suppliers of primary products with respect to production costs, raw ma erials sources, entry conditions, scale of operations and concentration. The main cost to secondary producers is the price of scrap zinc. New scrap zinc is generated by consumers of slab zinc who make galvanized steel, die castings, brass, and other zinc products; old scrap is reclaimed from discarded zinc products. New scrap accounts for about 80 percent of total scrap supply, and die castings and brass account for the bulk of new scrap.

Entry into the secondary market is easier than into the primary market, as access to secondary raw materials

(scrap zinc) is much easier than access to primary raw materials (mined zinc), and the time horizon for entry or capacity adjustment is shorter for the secondary than for the primary sector. The secondary zinc sector, and the scale of operations of a secondary producer is typically very small relative to that of a primary producer. Of all domestic distilled and electrolytic zinc, primary refineries account for about 93 percent. The share of secondary producers in U.S. consumption of zinc has remained roughly constant over the past decade. As the supply of secondary zinc is closely tied to past consumption, it is insensitive to the price of zinc except perhaps in the short run.

COMPOSITION AND DISPOSITION OF
U.S. SUPPLY OF ZINC, 1970
(Thousands of Short Tons)

Components of U.S. Supply (and % of Total)		Disposition of Supply (and % of Total)	
U.S. Primary Production	1059.8 (57.9%)	U.S. Consumption	1643.9 (89.8%)
Imports of Metal	270.4 (14.8%)	Industry Stocks	187.9 (10.2%)
Secondary Metal	332.4 (18.1%)	Exports	0.29 (neg. %)
Industry Stocks	168.2 (9.2%)		

After primary and secondary production, imports are the third largest contributor to domestic supply, accounting for 14.8 percent in 1970. The share of

imports in total U.S. consumption has risen from less than 10 percent to about 23 percent over the 1960-1969 period, and is likely to increase still further. It appears that the decline of U.S. smelting capacity relative to consumption is contributing most importantly to this import displacement. The major exporters of zinc to the United States are Canada, Australia, Mexico, Peru and Japan.

Although there seem to be substantial international competitive pressures, national market structures vary. In France production is carried on under practically monopolistic conditions. Competitive forces in the United States appear to be much stronger, although the market is concentrated. The geographic scope for competition in zinc lies somewhere between the two extremes of a national market subject to peripheral import competition and a cohesive world market where economic and political barriers are negligible.

The U.S. zinc industry contains both integrated and nonintegrated producers, with the latter including independent mining firms and custom smelters and refiners. The integrated firms own mines and mills as well as smelting and refining plants. A much larger part of their zinc output is refined from concentrates produced by their own mines and mills. Custom smelters purchase concentrates from other foreign or domestic companies and either smelt or refine or both. The distinction between custom refiners and independent producers is not absolute, as some custom refiners own mines and integrated firms do some custom work.

Refining is a more concentrated activity than is mining, both in the United States and abroad. In 1966,

ten integrated domestic producers accounted for about 90 percent of total U.S. primary and secondary zinc, and for about 55 percent of total U.S. output of mined zinc. In the noncommunist world, the primary capacity of thirty-two integrated primary producers accounted for 90 percent of world production. In world mining, integrated primary producers contributed at least 15 percent of mine production. Secondary zinc involves a much lower degree of integration than does the primary sector. The U.S. industry is now even more concentrated, as seven firms, most of which do some custom work, account for all domestic primary zinc.

An indicator of the degree of concentration is world concentration in primary zinc refinery capacity. In our 1969 report to GSA, we indicated that the top four firms' refining capacity accounted for 23 percent of the total noncommunist world production. The top eight firms accounted for nearly 40 percent, and the top twenty firms for nearly 72 percent. Domestically, the top four firms accounted for about 96 percent in 1963. It appears that the U.S. industry is becoming increasingly concentrated, and that foreign producers will increase their share of the domestic market at the expense of domestic production. Both of these trends are attributable to the decline of relatively high-cost mines and smelters abroad.

Chapter 5
PRICES OF ZINC

The benchmark quote for domestic zinc prices is the producers' quoted price for prime western slab zinc, the grade used in galvanizing. In recent years, East St. Louis was used as a basing point, with a delivered price equal to the East St. Louis quote plus $0.005. In January 1971 the zinc industry abandoned the East St. Louis base price in favor of a flat delivered quote for all domestic sales. The change amounted to a $0.005 price cut in the delivered prime western price. High-grade and special high-grade zinc, used in die casting and brass, are priced at quoted differentials above prime western. The effect of the January price policy change was to reduce that differential from about $0.01 to $0.005. Zinc is often sold at a discount below the producers' published price, but infrequently at a premium. Adherence to the published price is generally stronger than in the case of lead, however. Concentrate prices tend to be closely associated with the prime western quotes.

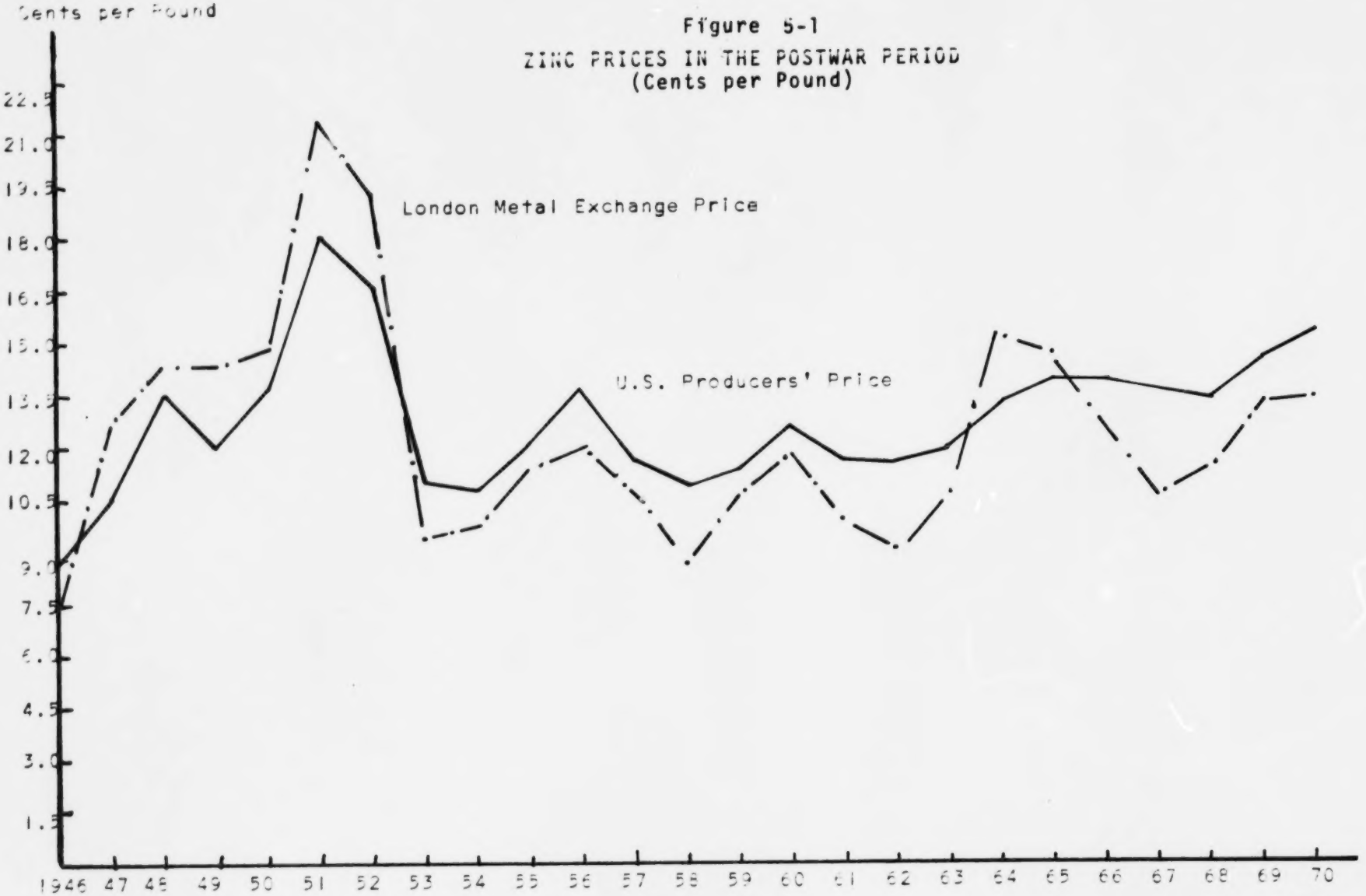
In the case of zinc, foreign and domestic prices have been more closely associated than are lead prices. Until 1965 the price basis for foreign sales of zinc was the London Metal Exchange (LME). Since 1964, however, zinc sales abroad have been made on the basis of a common price set by producers under the leadership of the Imperial Smelting Corporation of Britain. This price has been changed very infrequently and has apparently been adhered to by all major foreign producers. In the seven years since the producers' price was adopted abroad the LME price of zinc has been considerably more stable than in the past, and has been at a stable discount from the producers' price. This discount reflects various warehousing costs for LME zinc. The U.S. producers' price has also been more stable since the introduction of the European producers' price.

Figure 5-1 shows the postwar history of the U.S. producer and the LME prices of zinc. The two prices are highly correlated, which is natural given that transport costs and duties are relatively small. The U.S. price tends to be several cents above the LME price, and above the European producers' price by a bit less, reflecting the level of transport costs and duties.

Earlier CRA studies of the zinc market found the behavior of zinc prices to be more suggestive of a concentrated industry than in the case of lead. This is especially so for foreign production. The European producers' price shows many of the signs of a fairly

Figure 5-1

ZINC PRICES IN THE POSTWAR PERIOD
(Cents per Pound)



SOURCES: *Minerals Yearbook*, 1946-1969.
Metal Statistics, 1970.
U.S. Department of Commerce, *Survey of Current Business*, various issues

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successful arrangement operating within the framework of a market structure that prevents persistent and substantial deviations from a competitive price level but which permits a significant degree of price discipline for periods of a year or more.

European price changes have appeared to be initiated by a well recognized leader, with signs of prior consultation among the major producers. Adherence to the quoted price appears to be the rule, but discounting in response to competition from outside the group has been evident.

The existence of relatively more successful cooperation among foreign producers, together with the greater share of zinc imports in total U.S. supply, has left less room for price discretion among U.S. producers than in the case of lead. Nonetheless, the price history of zinc is consistent with the hypothesis that there is a fairly stable mark-up between long-run average costs and price. This mark-up is in the nature of an administered price with a strong element of price leadership, particularly by the lower cost producers, which takes into account the behavior of foreign prices.

In the past, price changes on one continent have more often been matched by similar price changes in other markets rather than accompanied by large changes in trade flows. Moreover, the response of producers in each market to a weakening of demand is generally to cut back on production and accept surplus capacity rather than to divert output to other national markets.

It is neither that competition of this sort is absent nor that domestic producers can ignore the competitive reactions of foreign producers, but it appears that there is appreciable room for discretion.

Prices increased substantially between 1947 and 1951, then fell sharply in 1953. Since then, both the LME and the U.S. price have shown little trend in real terms, trending slightly upward in nominal terms along with general economic inflation. In 1971 the European producers' price has increased from £127.95 per ton -- or $0.139 per pound -- in January to £150 -- or $0.168 -- in June, at which level it has held steady.

The U.S. price has followed this trend, rising from $0.15 to $0.17 from January to August. The evidence suggests that the principal reason for this price increase is that foreign demand and smelter capacity expansion have bid up the price of relatively scarce concentrates on the world market, and that the U.S. price, given the U.S. dependence upon imported concentrates, is being pulled along. Though their rise in concentrate price appears to have run its course, the higher cost of concentrates is an important factor in the closing of relatively high-cost zinc smelters in the United States.

The stable mark-up between average cost and price is likely to persist in the future. Long-run average costs have remained fairly constant, although there is some evidence of a moderate increase in the past few years. Under normal market conditions, the price of zinc over the next five to ten years will probably be in the range of $0.16 to $0.17 per pound (in 1970 dollars), or approximately

equal to the average historical (deflated) value since the Korean War. (See Table 5-1.)

Table 5-1

EAST ST. LOUIS PRICE OF ZINC, PRIME WESTERN GRADE, DIVIDED BY THE WHOLESALE PRICE INDEX ALL COMMODITIES (1957-59 = 100)

(Cents Per Pound)

1955	13.19
1956	14.03
1957	11.51
1958	10.27
1959	11.38
1960	12.86
1961	11.51
1962	11.56
1963	11.96
1964	13.50
1965	14.15
1966	13.69
1967	13.04
1968	12.42
1969	12.92
1970	13.08

Source: The nominal price was taken from *Metals Week*, and the Wholesale Price Index from the USDC, *Statistical Abstract of the United States*, 1970.

Chapter 6
GOVERNMENT POLICIES IN THE ZINC INDUSTRY

The U.S. government has been involved at various times since 1941 in influencing exploration, production, stockpiling, consumption, and pricing of zinc.

Stockpiling

Wartime stockpiling, initially suggested in May 1941, grew to 275,000 short tons of slab zinc by 1947. Various congressional acts and government programs, including the Strategic and Critical Materials Stockpiling Act (1946), the Defense Production Act (1949) and the Commodity Credit Corporation's Barter Act, pushed federal stocks of zinc to a maximum quantity of 1.58 million short tons of slab in 1963. Disposal of zinc for government and commercial consumption was begun in July 1964, and inventories decreased to 1.16 million tons by the end of 1968. Following evaluations of the availability of secure Mexican and Canadian supplies of zinc and estimations of domestic

productions trends and capacities, a stockpile objective of 560,000 tons was established by GSA on December 3, 1969. Stocks, therefore, were greatly in excess and disposals were continued. In October 1971, GSA declared that 536,000 tons of zinc were in excess of the target.

In October 1971 letters of agreement were signed by all U.S. primary zinc producers and GSA. These agreements provided for annual producer purchases from the stockpile of up to 50,000 tons of zinc. The purchase period will stretch over about 10 years, with amounts allocated to individual smelters according to their 1970 production. The allocations are subject to review every three years. The disposal rate may be altered or suspended in times of market surplus, as measured by the ratio of primary smelter stocks to the previous year's domestic primary shipments. The metal will be priced at published quotations with individually negotiated discounts to cover reworking, handling, and distribution costs. Both the GSA and industry officials expect to complete their arrangements in time for Congress to authorize sales in 1972. Release of 50,000 tons would probably have no effect on zinc prices, but would probably reduce the share of domestic supply stemming from imports, as 50,000 tons represents about 19 percent of 1970 zinc metal imports.

Tariffs and Surcharges

Government intervention in the foreign import market through tariffs and the present surcharge has also affected the zinc industry. The U.S. Tariff Schedule imposed charges of $0.0067 per pound on the zinc metal from 1965 to

August 1971. Statutory duties were $0.0167 per pound of zinc content and $0.0175 per pound, respectively. Statutory rates, dating from 1930, apply to countries that have not been granted duty preferences or concessions. Further, they pertain to all products subject to the August 1971 surcharge if the sum of their pre-August duty plus 10 percent of the invoice value, f.o.b. the foreign port, exceeds the statutory rate. The London Metal Exchange (LME) price of zinc in mid-October 1971 was about £135 per metric ton or $0.149 per pound. The pre-August tariff plus 10 percent of this price is $0.0219 per pound, which exceeds the statutory rate. Thus the current tariff and surcharge applying to zinc is $0.0175 per pound. If about $0.0125 per pound is added for freight and delivery charges, then the cost of acquiring zinc from LME is about $0.179 per pound, which is $0.009 above the October domestic price of prime western delivered.

It appears that foreign producers of zinc are absorbing the surcharge for the short term, lowering their product prices to maintain their shares of the U.S. market. According to *Metals Week* (September 6 and 13, 1971), most Canadian producers will ship zinc to the United States at pre-surcharge prices, and Canada is the major source of U.S. zinc imports. Furthermore, the Canadian government has announced its willingness to subsidize two-thirds of the cost of the surcharge for all exporting companies that would otherwise be forced to lay off employees. As of October 1971 no announcements of application for such assistance had been made.

Japanese producers are reportedly hesitant about absorbing the surcharge and may seek to send their exports elsewhere. Such action would tend to eliminate the relative attractiveness of other markets, so that the surcharge may well be absorbed as long as it is maintained. The resolution of the issue will in any case not be apparent until the current U.S. dock strikes have ended. In view of the fact that the U.S. depends heavily upon imports, especially of concentrates, it may well be reasonable to expect a removal of the surcharge on imports of zinc concentrates, and perhaps on zinc metal, in the near future.

Zinc is one of the few metals whose price at the time of the August 1971 freeze was above its level of May 25, 1970. The price of prime western zinc was then $0.15 per pound, from which level it subsequently declined, then turned and rose steadily to its current level of $0.17 per pound. Thus it is currently pegged at that level, which is slightly below the foreign price. Such a discount for the U.S. price has made it difficult for U.S. smelters to compete for concentrates, which until recently were in short supply on world markets.

Other Policies

Historically, the zinc industry has experienced numerous stimuli from government programs. The amended Defense Production Act of 1950 authorized federal subsidization of zinc exploratory activities up to 50 percent of approved expenditures. Public Law 85-702, enacted in 1958, perpetuated this program under the

Office of Mineral Exploration until June 1962 when zinc was determined to be no longer eligible for subsidy. The Lead-Zinc Small Producers Stabilization Act of October 1961 entitled eligible domestic producers of lead and zinc ores and concentrates to subsidization. Federal payment reimbursed 75 percent of the difference between $0.145 per pound of zinc content and the average monthly prime western price. On May 1, 1969 the ceiling rate was reached and the program was suspended. During the eight-year life of the latter aid program $2.59 million dollars were expended on sales of 35,832 tons of lead and 68,860 tons of zinc. Ninety-one producers dispersed in 11 states received federal subsidy with Oklahoma receiving 26 percent of the total dollar support.[1]

In the area of foreign trade, the federal government imposed import quotas on zinc ores, smelter products and metal under the authority of the trade Agreement Extension Act in October 1958. Quotas were apportioned on the basis of 80 percent of the U.S. average annual imports of the above materials from 1953 to 1957. Prominent exporting countries were allocated individual limits. Seven years later, investigations by the Tariff Commission led to the termination of the import quotas on October 22, 1965 for zinc ores and November 21, 1965 for zinc metal.

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[1] *Minerals Yearbook (1969)*, p. 1145.

Chapter 7
THE ZINC INDUSTRY IN THE UNITED STATES

Figure 7-1 shows the trends in activity in the U.S. zinc industry from 1948 to 1970.

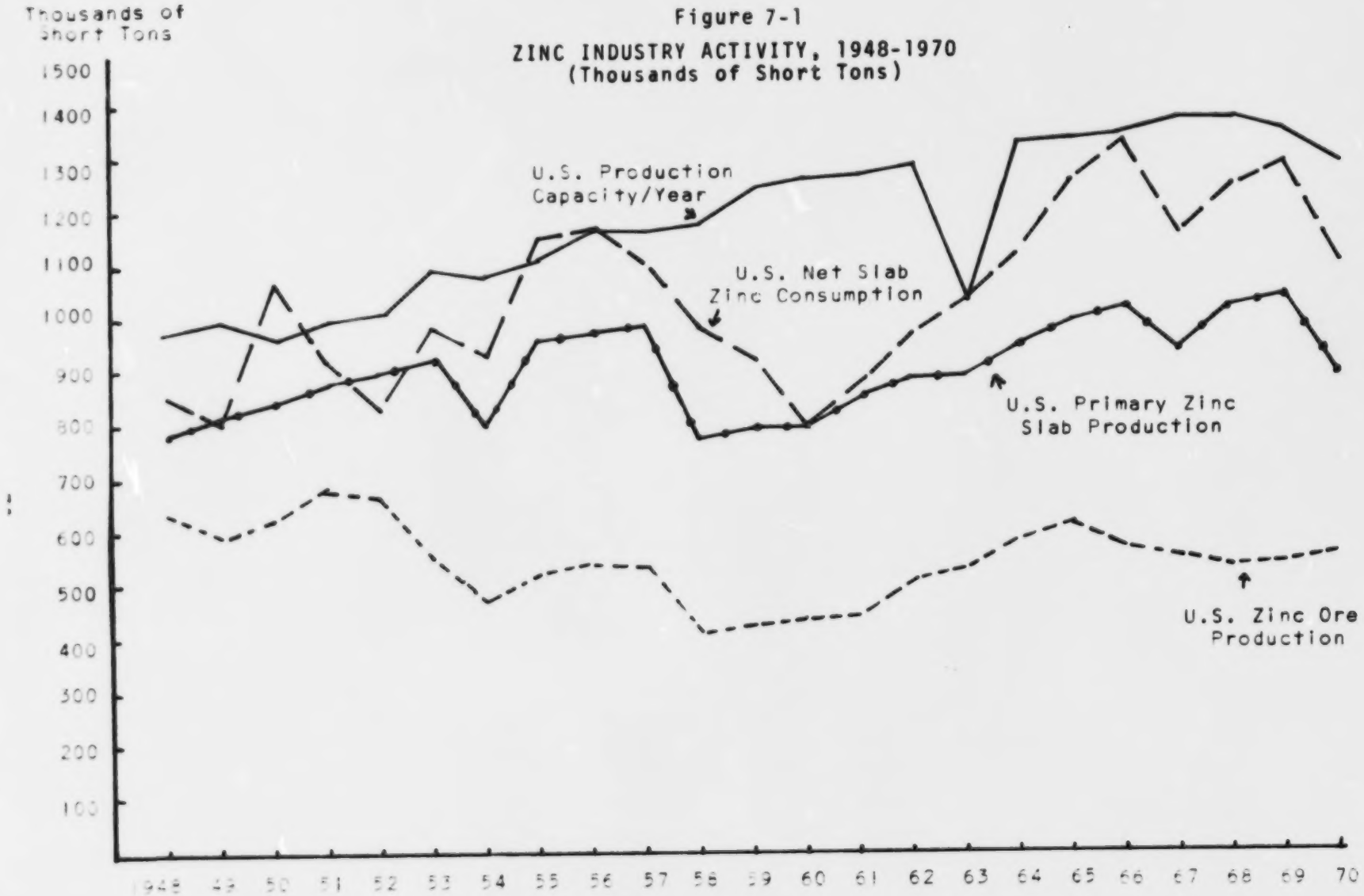
The zinc industry through the smelting and refining stage of production can usefully be categorized as consisting of a low-cost and a high-cost sector. This categorization rests partly upon the nature and location of ore supplies, and partly upon smelter technology. For this reason, our discussion of the industry includes these topics.

Ores and Mines

There are three zinc mining regions in the United States distinguished by the local type of ore. Ores are classified on the basis of the recoverable metal of major value contained: zinc ores, lead-zinc ores, lead ores, and all other ores from which some zinc is obtained.

Figure 7-1

ZINC INDUSTRY ACTIVITY, 1948-1970
(Thousands of Short Tons)



SOURCES: ABMS *Yearbook*, various issues. Net slab zinc consumption was calculated by subtracting production of redistilled secondary (excluding resmelt and remelt zinc included in the Bureau of Mines consumption) plus net exports from total domestic consumption of slab zinc.

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PERCENT OF DOMESTIC ZINC PRODUCTION
OBTAINED FROM ORES BY TYPE, 1969

Ore Type	Percent of Domestic Ore Production
Zinc	63%
Lead-Zinc	18
Lead	9
All Other	10

SOURCE: U.S. Bureau of Mines, *Minerals Yearbook*, 1969.

In the eastern states, ores are primarily in the zinc category. Ores in the central states are of the lead type, and in the western states lead-zinc and more complex composite ores predominate. New York, Tennessee, and New Jersey are the major ore reserve states in the "East of the Mississippi" category.

ESTIMATED ZINC ORE RESERVES
(Millions of Short Tons)

Area	Reserves
East of the Mississippi River	21.7
Arkansas, Kansas, Missouri, Oklahoma, Texas	5.3
Arizona, Colorado, New Mexico, South Dakota, Utah, Wyoming	5.8
California, Nevada	0.3
Idaho, Montana, Oregon, Washington	2.6
TOTAL	33.7

SOURCE: U.S. Bureau of Mines, *Minerals Facts and Problems*, 1970.

NOTE: These figures may not include recent expansions in New York, Tennessee, and Missouri.

The increasing prominence of Missouri and Tennessee are apparent from the data on domestic mine production by state. The position of Tennessee seems likely to continue to strengthen considerably. In early 1969 a major ore discovery in central Tennessee was announced. Although the deposit is not fully explored and developed, initial analysis indicated ore reserves of 13 to 50 million tons with the strong possibility that further exploration would reveal up to several hundred million tons. Mine output from this new deposit could be expected in 1973 or 1974 if exploration continues to produce favorable results.

U.S. MINE PRODUCTION OF ZINC
(Short Tons and Percent of Total)

Colorado	40,246 (7.4%)	52,195 (9.5%)
Idaho	49,561 (9.1)	40,457 (7.4)
Missouri	4,380 (0.1)	51,865 (9.5)
New York	59,111 (10.9)	57,667 (10.5)
Tennessee	46,025 (8.5)	120,201 (22.0)
Utah	42,374 (7.8)	36,687 (6.7)
TOTAL U.S.	542,340(100.0%)	546,772(100.0%)

SOURCE: ABMS *Yearbook*, 1970 and 1965.

The improving position of New York is not reflected in the data presented above. However, recent developments at the zinc mine and mill at Balmat, New York, served as the basis for a prediction that this facility alone will eventually supply about 20 percent of the

zinc mined domestically.[1] The application of highly mechanized, trackless mining technique and automated milling will make this a relatively low-cost ore source. Another important aspect of the state mining data is the similarity of 1956 and 1970 production levels. Although mine production has fluctuated from year to year, with outputs from 1964 to 1966 being somewhat larger, there has been no trend over the past decade and a half. Output in many central and western states has declined considerably while it increased in the eastern states. Montana mines, for example, produced 70,520 tons in 1956, and about 5000 in 1970. It is important to note that of the three low-cost smelters currently in operation, two are located in the eastern states and draw substantial portions of their ore supplies from Tennessee and New York. The third low-cost smelter also recently acquired important mining properties in Tennessee from another company which has withdrawn from the primary zinc industry.[2]

Ores from domestic mines provided domestic smelters with about 50 percent of 1970 requirements -- the remainder being imported. Thus the zinc smelting industry is considerably more dependent upon foreign ores than is the lead industry, which imports about 17 percent of its ores.

Employment and Labor Productivity in Zinc Mining

Detailed employment statistics are not available for the domestic zinc industry. The Bureau of Mines estimated that about 10,000 production workers were employed in lead and zinc mines and mills in 1968. The 1970 edition of the *International Directory of Mining and Mineral Processing*

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[1] *American Metals Market*, October 26, 1971.

[2] *Ibid.*, December 1, 1971.

Operations (Published by *Engineering and Mining Journal*) estimates that 14,800 persons were employed in zinc-producing mines and mills in 1970. The bulk of this employment is in a few states, but many states are sources of small amounts of output. Twenty-two zinc mining states, together with their annual production, are listed in the 1970 ABMS *Yearbook*.

According to the Bureau of Labor Statistics, output per production worker in the primary copper, lead, and zinc sector has increased at the average annual rate of 2.3 percent from 1947 to 1969. The number of production workers declined at a rate of 1.1 percent per year over the same period, but the rate of decline was 0.5 percent over the period 1957 to 1969. A similar profile is presented by indices of total employment in these industries.

Leading Domestic Zinc Mining Companies

The largest domestic producer of zinc ore is the New Jersey Zinc Company, whose mines are in New Jersey, Tennessee, Pennsylvania, Virginia, Colorado, and Wisconsin. St. Joe Minerals Corporation, the second largest producer, draws its ores mainly from New York, but also from Tennessee, Missouri, and other states. The major American Zinc Company mines are in Tennessee and Wisconsin, while Bunker Hill draws from Idaho. Nearly 20 companies report zinc concentrate production in the ABMS *Yearbook*.

PRODUCTION OF SOME LARGE
U.S. ZINC MINING COMPANIES
(Short Tons)

Company	1969
American Zinc Co.	74,699
ASARCO	21,240
Bunker Hill	33,921
Eagle Picher	32,068
New Jersey Zinc	(54,134)
St. Joe Minerals Corporation	79,059
U.S. Smelting Refining and Mining	25,333

Smelting and Refining

There are essentially four sources of supply of domestic smelted zinc: primary smelters, secondary smelters, imports, and inventories. In this section we shall discuss the secondary refineries briefly and the primary refineries in more detail.

Secondary Smelters

The production side of the secondary metal market is characterized by relatively easy entry, lower concentration, and a cost structure substantially different from that of the primary producers. The scale of operations of a secondary producer is typically very small relative to that of a primary producer. The bulk of secondary zinc is new scrap generated by consumers who make galvanized steel, die castings, brass, and other zinc-combining products. Diecasters and brass mills

recover most of the secondary zinc. Thirteen secondary slab zinc plants are listed in the 1969 *Minerals Yearbook*, although substantially more redistilled secondary slab zinc is produced at primary than at secondary smelters. Detailed output data for this sector, which accounted for about 332,400 tons or 18 percent of 1970 domestic supply, are not available.

Primary Producers

There are seven major primary zinc reduction companies, which produce all of domestic primary smelted and refined zinc. These companies operate eight smelters. Of these, the Anaconda plant at Great Falls, Montana is scheduled to close down in mid-1972.

ZINC SMELTERS IN THE UNITED STATES

Firm	Type of Smelter	Annual Capacity (Short Tons)
Anaconda		
Great Falls, Mont.	Electrolytic	162,000
ASARCO		
Amarillo, Tex.	Horizontal retort	53,000
Corpus Christi, Tex.	Electrolytic	108,000
AMAX		
Blackwell, Okla.	Horizontal retort	88,000
Bunker Hill		
Silver King, Idaho	Electrolytic	107,000
National Zinc		
Bartlesville, Okla.	Horizontal retort	63,000
New Jersey Zinc		
Palmerton, Pa.	Vertical retort	110,000
St. Joe		
Josephtown, Pa.	Electrothermic	210,000
Total		901,000

SOURCE: *Metals Week*, October 11, 1971, p. 31.

RECENTLY CLOSED U.S. ZINC SMELTERS

Firm	Type of Smelter	Annual Capacity (Short Tons)	Year Closed
American Zinc			
East St. Louis, Ill.	Electrolytic	84,000	1971
Dumas, Tex.	Horizontal retort	58,000	1971
Anaconda			
Anaconda, Mont.	Electrolytic	90,000	1969
Matthiessen and Hegeler			
Meadowbrook, W. Va.	Vertical retort	45,000	1971
New Jersey Zinc			
Depue, Ill.	Vertical retort	65,000	1971
Eagle Picher			
Henryetta, Okla.	Horizontal retort	55,000	1969

SOURCE: *Metals Week*, October 11, 1971, p. 31.

Anaconda

Anaconda is withdrawing completely from the primary lead and zinc industries. In mid-1969, when the company announced that it was shutting down its Anaconda, Montana electrolytic plant, it cited the shortage of concentrates as its reason. The inability to purchase zinc concentrates has again been given as the reason for closing the larger electrolytic plant at Great Falls. The Montana mines, which used to supply large amounts of concentrates, are no longer economic to work, due largely to their low ore grades, low by-product prices, and costly, labor-intensive operations. Canadian ores, which might serve as supply sources, are being shipped to European and

Japanese smelters, or retained for smelting in Canada. Anaconda has not mined zinc since 1968 and has been feeding its smelter with purchased and toll concentrates.[1] The Great Falls smelter has no acid plant or other method of recovering sulfur dioxide from the roasting process.[2] The plant and equipment are also rather old. The smelter is definitely within the category of high-cost producers. It employed 1500 people in 1970.

ASARCO

ASARCO operates two smelters in Texas -- an electrolytic plant at Corpus Christi and a horizontal retort plant at Amarillo. The horizontal retort plant was built in 1923, and has no acid plant for sulfur recovery. It produces galvanizing grade zinc, and for that reason it can treat some types of concentrates more efficiently

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[1]A custom smelter purchases ores and concentrates from mining companies that do not smelt their own output. The distinction between custom and integrated smelting companies is one of degree, as most primary producers purchase some ores from mines other than their own. St. Joe Minerals Corporation and New Jersey Zinc are among the more integrated companies, while ASARCO and Anaconda are among the custom smelters. The smelting company may sell the slab zinc on its own or on a commission basis for the mining company. If the mining company retains ownership of the material, the concentrates are said to be processed on a toll basis.

[2]Industry sources agree that high concentrate costs are sufficient reasons for closing the plant, but indicate that sulfur dioxide emission control costs would also be a sufficient reason unless concentrate costs became improbably low.

than can the Corpus Christi electrolytic plant, which produces higher purity grades. The plant obtains natural gas for fuel under long-term contract at what is described as a "good price." The plant may have less difficulty in securing concentrates on economic terms than the Anaconda plant at Great Falls. The old horizontal retort plant and equipment is the main reason for placing this smelter in the category of high-cost producers.[1] The Amarillo smelter employed 450 people in 1970.

The Corpus Christi electrolytic plant is regarded as modern and low cost. Although much of the concentrates treated are imported, ASARCO owns all or part of substantial amounts of the concentrates. The Gulf location is favorably suited with respect both to transportation costs and to disposal of the sulfuric acid produced by the smelter's acid plant. This facility should be regarded among the low-cost producers.

AMAX and National Zinc

Both of these facilities are horizontal retort plants which, along with ASARCO's Amarillo plant, are

[1] *Metals Week* of October 11, 1971 reported that "ASARCO's Amarillo plant is considered by many industry observers to be just living out numbered days under an extension of a local pollution-control ordinance." Industry sources also agree that it would not pay to install pollution control equipment sufficient to meet the proposed Federal standards. For reasons discussed in Chapter 8 of this report, this strongly suggests that profit margins in the absence of control costs are relatively small.

in the so-called "Gas Belt" region. As we pointed out in Chapter 2 of this report, smelters in this area were originally constructed because of local natural gas fuel supplies, suitable retort clays, and easy access to large ore supplies and Midwest consuming areas. The local ore supplies are now dwindling, however. AMAX owns important foreign ore sources and reportedly is considering the purchase of American Zinc's (closed) electrolytic refinery at East St. Louis, Illinois. AMAX's plant at Blackwell, Oklahoma, which has no acid plant, would probably be closed down should the East St. Louis plant be purchased. The Blackwell facility was built in 1916.

The National Zinc smelter at Bartlesville, Oklahoma was built in 1907 and also has no acid plant. According to *Metals Week* of October 11, 1971, "National Zinc appears to have the best capability of the three to meet the pollution-control requirements, but -- like the rest -- will have to be concerned about its concentrate sources in the future." The Bartlesville facility employed 500 people in 1970.

The old age of the plant and equipment, the nature of the technology and the increasing difficulty of obtaining concentrates place these smelters in the category of high-cost producers.

Bunker Hill

The Bunker Hill smelter at Silver King, Idaho is to some extent a custom smelter. It produced about 96,000 tons of slab zinc in 1970, while producing only 30,000

tons of zinc concentrates from its Bunker Hill and Star mines. An acid plant is in operation here, and sulfuric acid is being sold. Much of the company's ore supplies are drawn from the Coeur d'Alene region of Idaho. This region is comprised of relatively labor-intensive, high-cost mines, several of which have gone out of business over the last decade. According to the annual report of its parent company -- The Gulf Resources and Chemical Corporation -- Bunker Hill earned only $1.8 million on sales of $88 million, 69 percent of which was accounted for by lead and zinc. This rate of return on sales of only 2 percent is far below the 13 percent return on lead and zinc enjoyed by St. Joe. All this suggests that Bunker Hill is in the high-cost producer category. On the other hand, it has spent considerable sums on cost-reducing modernization, including the use of small trackless equipment in the Bunker Hill mine. The company may well constitute an intermediate cost category -- having lower costs than the "Gas Belt" horizontal retort plants but somewhat higher costs than St. Joe, New Jersey Zinc, or even ASARCO at Corpus Christi. The smelter employed 600 people in 1970.

New Jersey Zinc

The New Jersey Zinc smelter at Palmerton, Pennsylvania is a vertical retort plant. The company has rich ore reserves in several states, most notably in Tennessee. The newly discovered and extensive ore deposit in the central part of the state is largely owned by New Jersey Zinc. Other important deposits are in New Jersey, Pennsylvania, Virginia, and elsewhere. The company operates a sulfuric

acid plant and is favorably located with respect to water transportation for its shipment to market. This smelter is definitely within the low-cost category of domestic producers.

St. Joe Minerals Corporation

The country's largest zinc smelter is St. Joe's electrothermic plant at Josephtown, Pennsylvania. The electrothermic process is essentially a continuous vertical retort process in which the heat is generated electrically; it is regarded as being a highly efficient technology. The company's mines in Balmat and Edwards, New York are rich deposits, and low-cost trackless mining equipment is used extensively. The concentrating mill, opened in the fall of 1971, is the most highly automated mill in the United States. According to industry sources, this integrated facility will supply about 20 percent of the zinc ore mined domestically, making St. Joe nearly self-sufficient in ore reserves.[1] An acid plant is in operation at the smelter, and its location on the Ohio River is favorable for transportation costs. This facility is definitely in the low-cost category, and is perhaps the most efficient of domestic zinc producers.

Smelter Summary

The eight domestic primary zinc smelters, soon to be seven, can be categorized according to low- and high-cost production costs. The important factors determining

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[1] *American Metal Market*, October 26, 1971, and conversations with industry officials.

a smelter's placement in the low-cost category are access to low-cost ores, access to good water transportation, and relatively modern technology. The two Pennsylvania and one Texas smelter share these advantages. Bunker Hill in Idaho is probably in a somewhat higher-cost position owing to the nature of its ore sources. The three horizontal retort plants share to some extent both the high-cost concentrate and the old technology problems. The Montana electrolytic plant is scheduled to close down because of inability to compete for concentrates. Industry sources indicate that the concentrate problem may be less severe at the Amarillo, Texas plant than the others, while the Bartlesville, Oklahoma plant may have less severe pollution-control problems among the high-cost producers.[1]

Financial Data

To give some indication of the size of the companies in this industry, Tables 7-1 and 7-2 present data on pertinent financial variables of the major lead and zinc producers. The data on sales, income, capital expenditures, and profit rates may be compared with the estimated costs of pollution control presented in the following

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[1]A possible source of substantial cost differences among the various smelters that is not covered in this report is the variation in pollution-control standards enacted by the individual states. Industry sources indicate that Illinois, Pennsylvania, Texas, and Montana may impose significantly more stringent standards than those being considered in this report.

Table 7-1
FINANCIAL DATA ON MAJOR LEAD AND ZINC PRODUCERS
(thousands of dollars)

Company	Net Sales	Net Income	Operating Income	Stockholder's Equity	Capital Expenditures
AMAX					
1970	840,720	83,600[1]	115,130	609,700	110,201[2]
1969	753,490	69,090	99,850	553,100	152,710
1968	570,590	59,770[3]	81,370	455,200	101,210
Anaconda					
1970[4]	977,424	63,787	108,845	1,188,375	90,500
1969	1,410,608	99,313[5]	393,128	1,166,172	127,016
1968	1,051,015	88,964	253,465	1,114,800	154,402
Asarco					
1970	717,636	111,718	58,634	676,562[6]	71,719
1969	770,982	100,808	62,361	640,745[6]	25,151
1968	634,081	78,617	39,701	587,120[6]	36,879
Gulf Resources & Chemical (Bunker Hill)					
1970	114,380	5,320	14,535	53,308	3,998[7]
1969	113,684	(8,917)[8]	12,083	49,237	5,453
1968	104,935	5,756	11,726	69,656	9,540
Gulf and Western (New Jersey Zinc)					
1970	1,629,562	44,771	118,112	580,346	86,676
1969	1,563,564	72,050	111,504	590,066	72,825
1968	1,330,565	70,366	147,526	537,874	61,587
St. Joe Minerals					
1970	161,303	26,210	53,097	164,576	15,227
1969	178,974	37,468	36,751	160,038	13,440
1968	150,812	24,973	28,368	135,667	10,304

Footnotes on following page

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Table 7-1 (continued)

FINANCIAL DATA ON MAJOR LEAD AND ZINC PRODUCERS

(thousands of dollars)

Footnotes:

[1] Includes earnings of RST International - 1970 of $11,500,000.

[2] Excludes $82.7 million cost of additional investment in RST International.

[3] Before net gain of $7,580,000 Re: Salcot Palabora Mining and loss at plant.

[4] Excluded from consolidated subsidiaries in Chile.

[5] After additional Chilean participation in profits of $51,937,000.

[6] Common stockholder's equity.

[7] These figures are net capital expenditures.

[8] Mainly due to Gulf's write-off of Mexican operations at Vera Cruz and provision for losses on discontinued operations in 1969.

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Table 7-2
FINANCIAL DATA ON MAJOR LEAD AND ZINC PRODUCERS: PROFIT MEASURES

	Net Income / Net Sales	Operating Income / Net Sales	Net Income / Equity	Operating Income / Equity
AMAX				
1970	9.94%	13.69%	13.71%	18.89%
1969	9.17	13.25	12.49	18.05
1968	10.48	14.26	13.13	17.88
Anaconda (International Smelting and Refining Co.)				
1970	6.55	11.14	5.57	9.16
1969	7.04	27.87	8.52	33.71
1968	8.46	24.12	7.98	22.74
Asarco				
1970	15.56	8.17	16.51	8.67
1969	13.08	8.09	15.75	9.75
1968	12.40	6.26	13.39	6.76
Gulf Resources & Chemical (Bunker Hill)				
1970	4.65	12.71	9.98	27.27
1969	-7.84	10.63	-18.11	24.54
1968	5.48	11.17	8.26	16.85
Gulf & Western (New Jersey Zinc)				
1970	2.75	7.25	7.71	20.35
1969	4.61	7.13	12.21	18.90
1968	5.29	11.09	13.08	27.43
St. Joe Minerals				
1970	16.25	32.92	15.92	32.26
1969	20.93	20.53	23.41	22.96
1968	16.56	16.82	18.41	18.70

Source: Annual Reports of all companies; and Standard and Poor, *Corporate Records*, October and November, 1971.

chapter. It would appear that the estimated capital costs of control facilities for the zinc operations of individual firms are small relative to the financial resources available to these companies. However, this is no indication of the impact of such costs on the profitability of these firms. In addition, most of the firms in question have substantial operations in other nonferrous metals industries, and will probably also have to invest in pollution-control equipment for these industries.

Analysis of the Cost and Profitability of Lead and Zinc Production in the United States

Our discussion of the domestic primary zinc industry has focused on the basis for distinguishing between low- and high-cost smelters. In this section we attempt to estimate those costs. Because of the limited availability of appropriate data, we have not been able to obtain precise estimates of cost or to perform statistical analysis of cost functions. However, there are data available that permit us to estimate the level of costs for the low-cost producers; the results correspond to our impressions obtained from both the trade literature and our conversations with zinc industry executives.[1]

The analysis focuses on the St. Joe Minerals Corporation, which is one of the largest domestic producers of lead and zinc, whose operations are largely confined to those metals, and whose annual reports contain more detailed data on the operations of a firm than are available anywhere else. The data is accounting data and does not necessarily reflect causal relations within any given

[1]See our 1967 report to GSA for further detail on this method of analysis.

year. The data alone are insufficient either to refute or to establish that St. Joe is in the category of low-cost producers or that St. Joe's costs are typical of other firms in that category. For reasons discussed earlier in this chapter, however, we believe that such is very likely to be the case. On the basis of our examination of St. Joe's income statements, we conclude that for normal levels of production, their average costs of production are about $0.082 per pound for lead and about $0.12 for zinc. St. Joe's profits as measured by rate of return on equity appear to be inexcess of what might be considered the marginal rate of return on new equity capital for the economy as a whole and are probably sufficient to attract capital into both lead and zinc production.

Calculation of Costs

The annual reports of the St. Joe Minerals Corporation present data on gross profit for the company, percent of gross profit attributable to each product, revenue from each product, and quantities produced and sold for each product. This information permits the calculation of cost, both total and average, for each metal from the following relation:

Gross Profit = revenue - variable cost.

Rearranging this relation and using 1970 annual report data, we obtain the following results:

Variable cost of lead = (price per ton) x (tons sold - tons purchased) - (percent profits due to lead) x (gross profits)

= ($312.38) x (190,759) - (0.67) x ($42,882,079)

= $161.766 per ton or $0.081 per pound.

The comparable figure for 1969 was $143.729 per ton or $0.072 per pound, and for the average of the years 1961-65 was $178.00 per ton or $0.089 per pound.[1] As 1969 was a very good year for the company while 1970 was not, the long-run average direct cost under current technology may well lie between $0.072 and $0.081 per pound.

An estimate of average total cost for lead is obtained by allocating overhead, general and administrative expenses, selling expenses and various other fixed costs, and by considering revenues from operations other than primary activities. The calculation performed is to subtract the amount labeled "other income" in the income statement of St. Joe from the figures labeled "administration, selling and research, strike and shutdown expense, mine development and exploration, depletion, depreciation and amortization, and interest." We call the remainder "net overhead expense."[2] The data from the 1970 annual report yield $14,853,062 - $9,169,661 = $5,633,401. Dividing this total zinc and lead metal production tonnage (tons sold minus tons purchased), which was 413,700 tons in 1970, we get $13.74 per ton or $0.007 per pound, as net overhead cost. Adding this

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[1] In our 1967 report to GSA the issues of by-product revenues, stability of cost schedule in money terms and sales from inventory rather than from current production were examined. The cost estimates presented appear to be reasonable when proper consideration is given to these problems.

[2] An alternate procedure would be to allocate all of the overhead expense to lead and zinc. The result would be an estimate of the overhead expense per pound that exceeds our estimate by $0.01. Use of this higher figure in our analysis below would not lead to any change in our conclusions.

to our estimate of average direct cost, we get $0.081 + $0.007 = $0.088 per pound as the average total cost of lead production in 1970. The results of such calculations for both lead and zinc are summarized in the following table.

	Year	Operating Cost Per Pound	Overhead Cost Per Pound	Total Cost Per Pound
	1961-65 Average	$0.089	$0.009	$0.098
Lead	1969	$0.072	$0.005	$0.077
	1970	$0.081	$0.007	$0.088
	1961-65 Average	$0.090	$0.009	$0.099
Zinc	1969	$0.104	$0.055	$0.109
	1970	$0.125	$0.007	$0.132

If the long-run average cost under current technology lies between the 1969 and 1970 figures, then the data presented above suggest that there has been a substantial decline in real production costs for the low-cost lead producers, and perhaps a moderate increase for low-cost zinc producers. Since 1965 the general price level (as measured by the GNP implicit price deflator for private production) has increased by about 20 percent.[1] If there had been constant real costs in each industry, nominal costs would have risen by 20 percent to $0.118 in 1970 for lead and $0.119 for zinc.[2]

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[1] *Economic Report of the President*, 1971, p. 201.

[2] The difference between the two industries' actual experience may be due to more rapid increases in zinc concentrate costs for zinc and to the fact that zinc production is more labor intensive than is lead production. Zinc costs have not had the same downward pressure from recent large scale, low-cost mine expansions as lead has experienced.

The result of the calculation, then, is that the long-run average costs for lead appear to be within the range of $0.077 to $0.088 per pound. Those for zinc may well be within the range of $0.109 to $0.132 per pound. Because the lower end of these ranges occurred in an unusually profitable year while the upper end of the ranges occurred in a relatively slack year, acceptable average costs estimates might be $0.082 for lead and $0.12 for zinc.

A second useful measure, in addition to our estimate of the lower level of production costs for the lead and zinc industry, is an estimate of the profit in excess of the normal opportunity cost of equity capital for the same group of producers. The calculations for this second estimate are based on less firm ground than are the cost estimates, and the conclusions are more tenuous. The results of the calculation will prove useful, however, in assessing the ability of the low-cost firms to attract new capital into the industry and to absorb exogenous cost increases.

The notion behind this calculation is that a given productive activity -- such as primary lead or zinc production -- will need to earn at least a normal competitive profit to continue in business. If the activity can earn a higher rate, it will tend to attract new capital for expansion and if it earns less than this rate it will have difficulty raising capital and will tend to decline. It is difficult to measure this normal competitive rate of return, taking risk and expectations into account, but the idea is powerful enough to warrant an approximation.

The measure adopted is the equity capital cost of production. The calculation uses the data provided by the St. Joe Minerals Corporation annual reports to allocate equity capital to lead and zinc production, to compute the competitive equity cost per ton for each metal, and to see if the difference between price and production costs is sufficient to cover this calculated competitive equity cost of capital. The calculations are illustrated in Table 7-3. At two stages in the calculations, some degree of arbitrary choice is involved: in choosing 7 percent and 10 percent as the competitive return needed to attract new capital into the industry in 1965 and 1969, and in allocating the total equity to lead and zinc roughly on the basis of their apparent long-run contributions to profits. Both choices appear to be reasonable, however.

The point to be made by this calculation is seen in comparing lines 4 and 7 in Table 7-3. There it is seen that the excess of price over average total cost is very large in comparison with the estimated cost of capital for lead. Although the numbers involved may not be entirely accurate, the orders of magnitude appear to be reasonable. The interpretation is that low-cost lead producers, as represented by St. Joe, are earning a rate of return on equity in excess of the return required for these producers to be able to compete with other sectors of the economy for new capital to finance expansion, and that their position in this respect has improved since 1965. In the case of zinc, there is also an excess of the earned over the competitively required rate of return, although it is less than in the case of lead and has diminished slightly since 1965.

Table 7-3

EQUITY CAPITAL COST OF LEAD AND ZINC:

ST. JOE MINERALS CORPORATION

(dollars)

	Company		Lead		Zinc	
	1965	1969	1965	1969	1965	1969
Stockholders' Equity[1]	$116,784,519	$160,037,778	$58,000,000	$80,000,000	$53,000,000	$72,000,000
Cost of Equity at a 7% rate of return[2]			4,060,000		3,710,000	
Cost of Equity at a 10% rate of return[3]				8,000,000		7,200,000
Equity Cost per Ton[4]			$ 30	$ 34	$ 18	$ 29
Average Price per Ton 1959-69 and 1969[5]			252	298	260	292
1969-70 Average-Total Cost per Ton[6]			136	164	200	240
Excess of Price Over Cost[7]			116	134	60	52

Source: St. Joe Minerals Corporation, *Annual Reports*, especially 1970.

Footnotes on following page.

Table 7-3 (continued)
EQUITY CAPITAL COST OF LEAD AND ZINC:
ST. JOE MINERALS CORPORATION
(dollars)

Footnotes:

[1] 50 percent of total equity is allocated to lead, and 45 percent to zinc. The remaining portion would be accounted for largely by iron.

[2] The equity allocated to each metal is multiplied by the rate of return assumed to be the competitive rate required to attract capital into the industry in 1965 and 1969.

[3] The equity cost was divided by the 1965 and 1969 tonnages of lead and zinc produced. For lead, the 1965 and 1969 tonnages were 133,600 and 233,160. For zinc the tonnages were 202,657 and 243,882.

[4] The 1969 costs of lead and zinc were taken to be $0.082 and $0.12, respectively. As the earlier text pointed out, these costs are within the range observed for 1969 and 1970 and are interpreted as the long-run average cost under current technology. The 1969 figures were deflated back to 1965 by dividing by 1.20. This is the amount by which the implicit GNP price deflator has risen since 1965, as discussed in the text.

[5] This is obtained by subtracting line 6 from line 5.

Summary

The low-cost lead and zinc producers, as represented by the St. Joe Minerals Corporation, appear to be in a strong position. Average real production costs have evidently been declining in lead and perhaps rising moderately in zinc. Currently these costs are about $0.082 per pound for lead and $0.12 per pound for zinc. Furthermore, the excess of price over costs appears to be more than adequate for the low-cost producers to bid competitively with the rest of the economy for new capital.

We do not have adequate data for making similar estimates of costs and profits for the high-cost sectors of the lead and zinc industries.

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